REGIONAL VARIATIONS IN MAORI GREENSTONE PENDANTS OF THE KURU STYLE

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Abstract. A multivariant statistical study of straight pendants suggests at least three types exist which have significant variations in distribution through northern New Zealand. The range of styles represented by the types appears to be prehistoric and reflect local styles.

In 1972, D. Wayne Orchiston published an exhaustive study of a collection of pendants in the Australian Museum and compared these with the Museum collection held at the Auckland Institute and Museum (Orchiston 1972a). This study concentrated on greenstone pendants of the straight form (*kuru*). On the basis of the technology employed in forming the perforation, the Australian Museum collection could be split into those which post-date the availability of European tools, and a second group apparently using traditional tools for the perforation — these being potentially prehistoric examples. The assemblage selected for study from the Auckland collection was all of the latter type. Orchiston's study looked for differences between the European tool-perforated group and the others, looked at relationships between dimensions taken off the pendants and dimensional differences between the two museum collections. On the basis that the European tool perforated group (Orchiston's E series) and the others (M series) were little distinguished when their metrical and other characters were studied, that *kuru* pendants are not as prominent in 18th century descriptions of Maoris while *kuru* are common in museum collections, that *kuru* are the most readily made of the Maori ornaments, and that, European supplied iron released nephrite tools for conversion to ornaments, Orchiston (1972a: 211) concluded "their number increased enormously during protohistoric times." In another paper Orchiston (1972b: 101) pointed to an apparent increase in the frequency of *kuru* pendants by Cook's third voyage visit to Queen Charlotte Sound as evidence that this change was a very early one. In respect of the M series *kuru*, the argument is not very secure and a prehistoric derivation for much of the assemblage is not disproven. In any event, from their method of manufacture M series *kuru* appear to be the products of the same technology that produced the prehistoric pendants and presumably products of much the same society.

Greenstone is a casual term which covers a variety of materials. The commonest is nephrite found in Nelson, Otago and Westland in the South Island (Ritchie 1976). Other nephrites are found in Central Otago. A related but softer material, serpentine, was also used for ornaments and some has a similar appearance to darker nephrites but is much softer. Some sources of this material are in Nelson but suitable material for ornaments may possibly be found in widely dispersed parts of New Zealand.

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Greenstone tools or ornaments or waste are not commonly found in excavated prehistoric sites. Two exceptions, Houhou pounamou (S 76/7) containing waste and Murdering Beach (S164/16) containing tools, ornaments and waste (Skinner 1959) are both in the South Island. However, greenstone tools and ornaments are not predominantly localised in the South Island. The localised examples of *kuru* covered in this paper are predominantly of northern North Island origin. Moreover, at least one variety of ornament, *pekapeka*, comes predominantly from the far north (Skinner 1974: 64) and Simmons (1971: 96) suggests that there are regional styles in *Hei tiki*, both records carrying the suggestion that manufacture of ornaments from greenstone was an activity dispersed through New Zealand.

There can be little doubt that greenstone was a prestigious material in prehistoric New Zealand, this being demonstrable from its unique distribution if nothing else. Many of the specimens now available to us may have passed through exchange relationships between different groups of Maoris. Elsewhere I (Law n.d.) have argued for the importance of these relationships in considering the regional diversity of prehistoric New Zealand. There is a considerable potential in New Zealand for studying the movement of common raw materials such as chert and obsidian (Leach 1977), but movement of more prestigious items might be expected to differ from this. If localised styles do exist in the forms of greenstone ornaments and tools the movement of these items could be open to study, although time control is always going to be difficult.

The inception of this study was the development by the writer of a computer programme for cluster analysis for application to adzes. The data on *kuru* were available from Orchiston and were used as test data but with the above in mind, with the additional aim of seeing if regional diversity existed in straight *kuru*.

Defining regional variations

Two alternate strategies may be envisaged for defining regional variations. One approach is to arbitrarily divide a collection of localised artefacts into regional groups. Once populations were so defined a study could be made using discriminant analysis or between-population distance statistics, or both, on metrical data from each population to determine the separateness of the populations. A second approach is to initially ignore the find localities of the localised artefacts and on evidence of their shapes develop a system of types with rules which will classify every artefact in the population. At this stage an arbitrary division of the localised artefacts into regional groups can be made and statistically tested to see if frequency of the types differs between regions. Both approaches may be biased by museum or donator selection in acquisition to museum collections. The second procedure suffers from the disadvantage that regional groups must be reasonably large to have any hope of showing significant differences and that the types found may be biased by over-representation of a region. However, it does offer distinct advantages, namely that unlocalised artefacts are included increasing the security of any differences discovered, and that the definition of types is of use to people studying other artefacts or collections of artefacts, and occasional items from dated contexts once typed can be used to evaluate the history of the forms. The second form of analysis is the one the author prefers.

The Population studied

From Orchiston's data, 113 M series pendants were available. A further three localised pendants were added, two being from the archaeological collections of Auckland Museum. Data for the extra three are listed in Table 1. Only 42 of the population are localised. Of the dimensions given by Orchiston, seven were selected for use in the clustering programme. These were:

1. The pendant length.
2. The distance from the centre of the perforation to the top end.
3. The perforation diameter at the neck, that is the smallest diameter.
4. The width at the perforation.
5. The width at one third of the length from the top.
6. The width at two thirds of the length.
7. The thickness at two thirds of the length.

All these dimensions were available for all pendants to the nearest 0.1 mm.

Table 1. Data for three localised pendants.

No.	Length		Perf.	Width			Thickness	Remarks
	Total	to perf.	dia.	At perf.	0.33	0.66	0.66	
NZ5/128	44.1	4.1	1.8	10.8	12.8	12.8	6.7	Sting Ray Pt. Pa, Gt. Mercury.
AR3820	64.7	5.3	2.5	8.3	8.2	7.8	4.6	Tahanga Quarry, Opito.
Private Collect.	70.8	3.2	2.1	6.4	8.1	8.7	8.8	Queenstown.
Dimension No.	1	2	3	4	5	6	7	

All measurements in mm.

The clustering procedure used can only deal with continuous variables, and not with alternate state or multi-state data. Consequently, some of the information given by Orchiston could not be used — in particular, the form of the edges, though some of the edge forms he describes are almost exclusively E series forms. The distal end form classification suffers from some confusion of geometric terms, and figures presented elsewhere are no clearer (Orchiston 1974, Fig. 2: 171). Three dimensions were not used, the maximum width, the thickness at one third of the length and the maximum thickness. These were judged to contain little more information than the seven selected.

Cluster analysis

This section is intended for the general reader. An appendix gives more technical details and discussion of choices made.

If two dimensions are measured on each unit (item) of a population and the values for each unit are used as plotting co-ordinates on a graph then a scatter plot results. Such a plot may show only one centre or mode, or it may show a number of clusters, each with a central point or mode. If each unit is assigned to a cluster, the cluster centre can be taken as the centre of gravity of the points so assigned. A measure of the success of such a clustering is the distance the units are away from their cluster centre. One such measure is the sum of all the distances squared, that is multiplied by themselves, and this is termed Sum Squared Error (SSE). If one dimension has a wider range than another, this dimension has a greater weight in these distances. There is no reason why any dimension should be so weighted so it is important to scale all the dimensions to have the same range. This is done so that looking at any one dimension alone then SSE is equal to the number of units (n), or more technically the variance (SSE/n) is unity. This process is called standardising. A second adjustment which is applied is to take the logarithms of the scores if this reduces the skewness of the distribution on any dimension. This ensures that scores above the mean do not have greater weight than those below the mean. If two dimensions covary then a large score on one dimension of a unit can be used to predict a large score on the other dimension of the same unit. If both of these two dimensions had only one mode (i.e. they were unimodal), then when the population points were plotted then they would form a cigar-shaped pattern. A quite efficient division into two clusters can be made of such a pattern with a cluster centre within each end of the "cigar". This does not reflect any real modes in the population and thus it is important to correct the data to remove this correlation. To do this for two dimensions, one is taken with no further modification while only that part of the second dimension which cannot be predicted from the first is further used. These residual variations are treated as a dimension and are scaled again so that the variance for the new dimension is unity. The two resulting dimensions are then uncorrelated.

The considerations above are not restricted to two dimensions but can be applied to any number of dimensions.

The clustering process applied to the data once converted, is one known as a 'K-Means' procedure described by Hodson (1971), M. Kendall (1975) and Hartigan (1975).

It will not be described fully here but its essence is that for a specified number of clusters it is attempted to find the best cluster centres for the population and success of any set is judged by the size of the value of SSE, the lower the better. As applied here once a clustering had been found a Mahalanobis distance was calculated for the distances between cluster centres and units and a unit was shifted to a new cluster if the Mahalanobis distance to that cluster centre was less than that to which it was assigned. A Mahalanobis distance is a more sophisticated distance measure which takes account of the shape of the clusters. This reassignment was iterative as shifting units alters the cluster centres and the distances. Such shifts usually result in small increases in the value of SSE. Mahalanobis distances can also be calculated between cluster centres. Such distances are referred to further below.

The clustering was performed using a computer programme "SUPERK", written by the author in ALGOL and run on the University of Auckland Burroughs B6700 computer.

Application

For these data all seven dimensions were logarithmically transformed as all had lesser skew in this form. Table 2 shows the correlation matrix for the seven dimensions so transformed.

Table 2. Correlation matrix of dimensions after log transformation.

		Dimension						
		1	2	3	4	5	6	7
	1	1.00						
	2	0.32	1.00					
	3	0.21	0.49	1.00				
Dimension	4	0.17	0.65	0.39	1.00			
	5	0.20	0.56	0.37	0.92	1.00		
	6	0.18	0.54	0.30	0.86	0.97	1.00	
	7	0.20	0.18	0.07	0.17	0.22	0.25	1.00

Lower half only shown. Dimension numbers as in Table 1.

As might be expected the three width dimensions show the highest correlations. A correlation of 0.18 or above suggests the correlation is at a statistical level of 'probably — significant' ($p = 0.05$ for null hypothesis of zero correlation, $n = 116$). Excepting the correlations of width there are no very high correlations in this population, as Orchiston observed.

Following removal of the correlations the data were clustered using from two to seven clusters. Figure 1 shows the best SSE values for each of the best divisions found with from two to seven clusters. As can be seen, there is a consistent improvement in the SSE as more clusters are allowed but this occurs even in unclustered data. The difficult point on any cluster analysis is to decide where valid clustering ends. The curve in Fig. 1 does not show any pronounced shoulder as might be expected if tight clusters existed. Plots of the distance between clusters and the Mahalanobis distance between clusters (Fig. 2) show little improvement after three clusters.

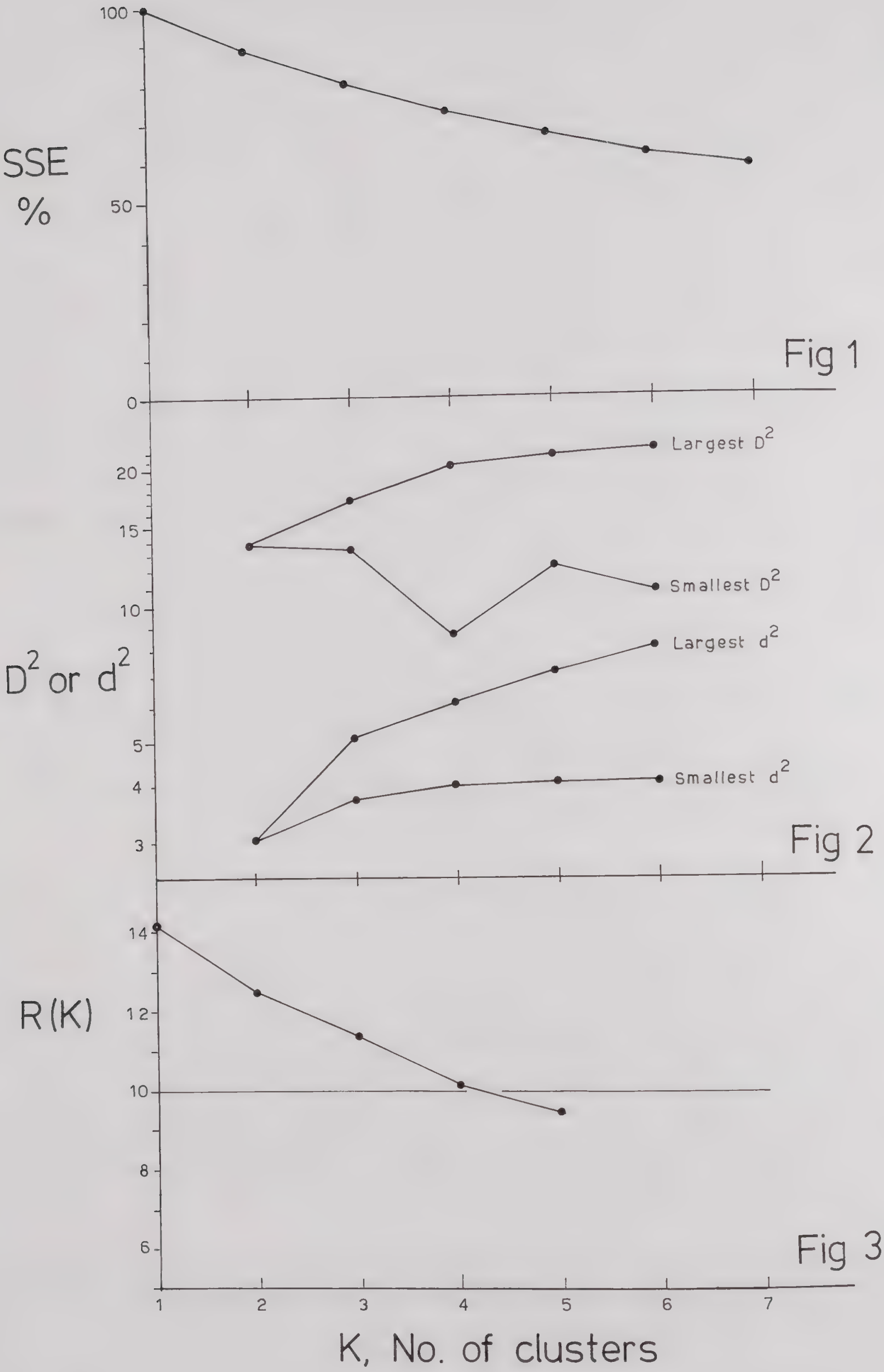
Hartigan (1975: 90) suggests that if the ratio

$$R(K) = \frac{SSE(K) \quad - \quad SSE(K+1)}{SSE(K+1)} \qquad (n-K-1)$$

is greater than about 10 then increasing from K to K + 1 clusters is justified. Here SSE (K) is the sum squared errors found for dimension into K clusters and n is the total number of units. This statistic is shown graphically on Fig. 3 and shows again no clear cut-off point though strictly applying the 10 cut-off would allow five clusters. The author must declare a bias against a large number of clusters in that when the distribution of the types is studied too many types will weaken the possibility of finding significant patterns given the limited number of localised specimens.

Clustering at the level of 3 types was adopted for the regional study. It must be emphasised that the success or otherwise of finding regional differences did not enter into the decision on the number of types to adopt, other than as noted above.

The characters of the three types are illustrated in Fig. 4. These are not actual pendants but synthetic pendants drawn from the parameters of the cluster centres. Table 3 illustrates the ways in which the types vary but it must be emphasised that attempts to classify pendants on even the two most useful measurements will meet low success.



Figs. 1-3. Variations of statistics with increasing numbers of clusters (K). 1. Reduction of SSE, the unexplained variance, with increasing K. 2. Greatest and least inter-cluster distances (D, Mahalanobis distances; d, Euclidean distances). 3. Ratio R(K) indicating validity of increasing from K to K + 1 clusters.

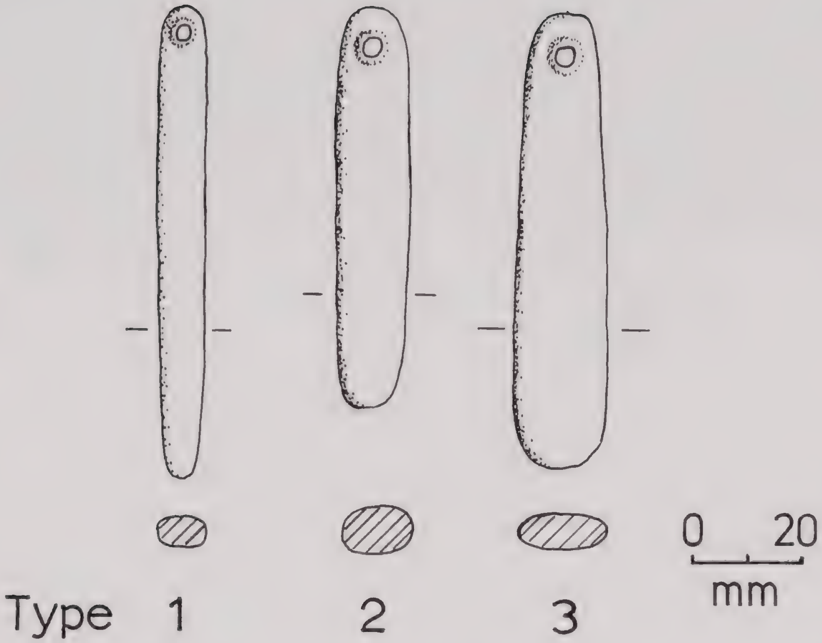


Fig. 4. The three pendant types represented by synthetic pendants drawn from the cluster centre parameters.

Linear discriminant functions can be given for the three types but are not included here. These types explain only a low proportion of the variance in the converted data. Over the seven dimensions they explain only 20% of the variance, and even over the most clustered two dimensions in the converted data, the three clusters explain only 43% of the variance.

The character table (Table 3) suggests types 2 and 3 are the closest together. This can be confirmed as the matrix of inter-cluster Mahalanobis D squared values shows this is the case (Table 4). However the way the units separated from the best K = 2 clustering into the best K = 3 clustering is contradictory (Table 5) showing the units in clusters 1 and 3 come predominantly from one cluster.

Orchiston (1974 2: 263) had previously suggested there were two varieties of *kuru* in Northland distinguished by their width, but the scatter plot from which the varieties were identified is not of itself convincing.

In conclusion it can be said that the population studied has a homogeneous character but imposed over that character are some weak modes which can be considered centres of diffuse clusters. It cannot be concluded that clear discrete types exist in the population. The utility of the types found must then depend on other criteria, namely are they significant when special or temporal data are used to group the data.

Regional variations

On completion of the clustering considerations the provenances of the pendants were studied. Figure 5 shows a distribution map for the three types. It should be noted that some locality attributions are to a district only and the plotted points are not all at precise find

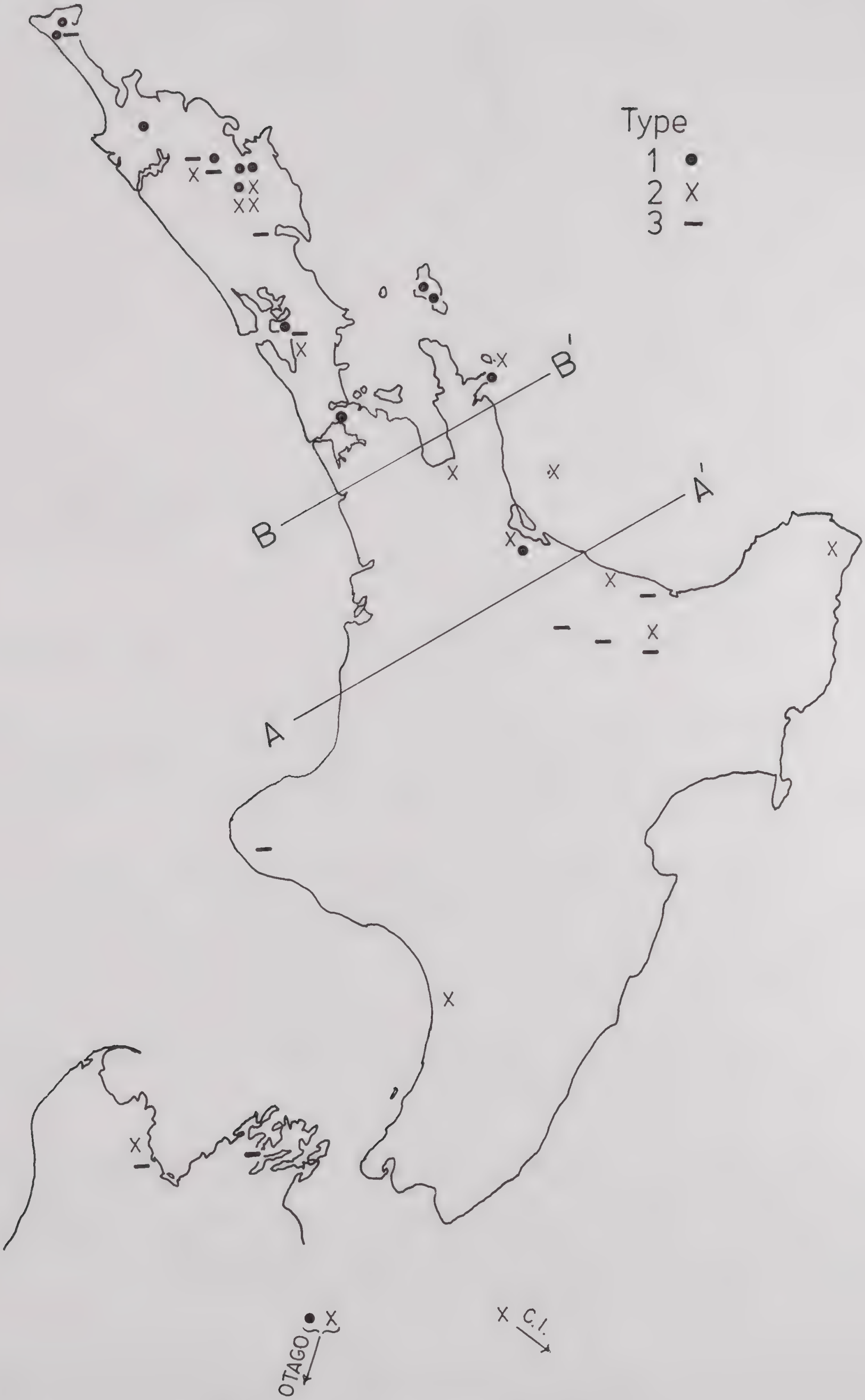


Fig. 5. Distribution map for pendant types.

Table 3. Characteristics of types.

Character	Type 1	Type 2	Type 3
Length to perf.	Short	Long	Long
Thickness	Thin	Thick	Thin
Width	Narrow	Wide	Wide
Plan Shape	Straight	Straight	Flaring

The characters are listed in order of significance.

Table 4. Inter-cluster Mahalanobis D-squared values.

		Cluster 1	Cluster 2	Cluster 3
	1	—		
Cluster	2	14.5	—	
	3	17.1	13.4	—

Table 5. Pendant transfers between clusters for K = 2 and K = 3.

		K = 3 Cluster 1	Cluster 2	Cluster 3	Total
K = 2	Cluster I	$\underline{19}$	12	$\underline{26}$	57
	Cluster II	8	$\underline{38}$	13	59
	Total	27	50	39	116

Figures underlined indicate the predominant derivations of the K = 3 clusters from the K = 2 clusters.

Table 6. Type localities by areas.

	Type 1	Type 2	Type 3	Totals
South of A-A’	1	7	7	15
A-A’ to B-B’	1	3	—	4
North of B-B’	12	6	5	23
Totals	14	16	12	42

localities. Moreover, four locality attributions Orchiston records as less secure have been accepted here. There is a noticeable concentration of types 2 and 3 in the eastern Bay of Plenty. If the population is split into two groups along the line A-A’ on Fig. 5, the distribution of the types is as in Table 6. This distribution is unlikely to have arisen by chance (Chi — squared probability of null hypothesis of no difference is less than 0.025). Moving the split line to B-B’ results is no less a significance suggesting the pattern is not sensitive to the choice of the division. Type 1 is over-represented in the northern area while type 3 is over-represented in the southern area.

Some other comparisons are of interest, such as type representations in collections (Table 7). The Australian Museum unlocalised collection (n = 38) is significantly different from the Northern area group (A-A' division) (Chi-squared p less than 0.005) but it does not differ from the southern area group. The Auckland Museum unlocalised collection is of similar size (n = 36). It does not vary significantly from either the northern subgroup or the southern. In view of the size of the southern area group (n = 15) establishing such a difference is not likely as the statistical methods used lose power with such small numbers.

Table 7. Type representations in collections.

	Type			Totals	
	1	2	3		
Australian Museum					
— localised	2	2	1	5	43
— unlocalised	4	14	20	38	
Auckland Museum					
Ethnographic Collection					
— localised	10	13	11	34	70
— unlocalised	9	20	7	36	
Archaeological Collection					
— localised	1	1	—		2
Private — localised	1	—	—		1
Totals	27	50	39		116

Despite the relatively unpromising results of the clustering, the three types decided on seem to have some utility and it would be valuable to extend the number of typed specimens in localities from the southern and western North Island, as well as the South Island. It is clear that the types do not have exclusive distributions. One or more of three processes might explain this. Firstly that the distributions were exclusively in space for manufacturing but exchange has blurred them, or secondly that the full range of styles was recognised and made in each area but the proportions made differed, or thirdly that each region had a single mode but more extreme examples cross the classification boundaries. These data are quite insufficient to look at these possibilities.

Time control

Only one of the pendants treated here is from controlled excavation. A type 2 pendant was recovered in the excavation of N40/11, Sting Ray Point Pa on Great Mercury Island. The site is pre-European but could date as far back as A.D.1400. A type 2 pendant was taken from the body of a defender at Gate Pa, Tauranga in 1864. The observations on pendants by L'Horme at Doubtless Bay in 1769 (Orchiston 1972a: 166) show the width to thickness ratios varied noticeably, perhaps over types 1 and 3.

A type 1 specimen from the summit of One Tree Hill (N42/6) can be suggested as a prehistoric specimen, perhaps earlier than A.D.1750 (see Fox 1977). The cluster of specimens from the Bay of Islands may well all relate to the burial caves known there. Two type 1 pendants come from Kawakawa, a type 1 and a type 3 from Ohaeawai, both definitely from burial caves, and three type 2's and a type 1 from Waiomio. If the latter are from burial caves, the date of the carved wooden burial chests from this valley may be relevant. A stylistic study of these by Fox (pers. comm. 1978), suggests these are late in sequence, though still prehistoric. Finally, a type 1 example from Tahanga adze quarry is unlikely to post-date the availability of steel tools.

This review of possible datings does little but suggest that the range represented by the three types is prehistoric.

Discussion

This present study adds to the literature suggesting greenstone ornaments differ between regions of New Zealand. This obviously has implications in considering the regional diversity of Maori Culture but has more specific implications for the material itself. To have regional variety, knowledge of the particular technology used for working nephrite must have been available throughout New Zealand, and suitable raw material or blanks (adzes?) must have been available. Both commodities must have passed through some exchange network to the artisans. The original quarry workers or middlemen in such an exchange would have had the option of converting the raw material into finished ornaments before exchanging it further. That they did not, suggests they were specialist traders at least in respect of nephrite. If they were optimising their behaviour, the rewards of exchange in handling minimally processed nephrite must have been greater than attempting to add value by further processing. In a situation where competition prevails, the rewards of exchange are the added value through transporting and marketing large volumes of material. But where a monopoly prevails, the rewards can result by limiting supply. This aspect of the exchange mechanisms and their microeconomics has been neglected in New Zealand. It would appear that data from nephrite tools and ornaments might be of use to compare with movements of more mundane materials.

Acknowledgements. For the opportunity to study the straight pendants in the Auckland Institute and Museum collections I should like to thank the Director of the Museum Mr E.G. Turbott and his staff. For facilitating access to the computer to develop the SUPERK programme for use by archaeologists, I should like to thank Professor Roger Green.

APPENDIX

FURTHER CLUSTERING CONSIDERATIONS

Clustering

A variety of procedures operate with a central aim of improving a global statistic (such as SSE) by shifting units between clusters where this improves the global statistic. All suffer from the fault that the outcome may be dependant on the initial cluster centres, and the less general tend to create clusters of equal numbers of units. In the case where the clusters are considered to be multi-variate normal distributions, likelihoods or log-likelihoods for the cluster sets can be found by linear mathematics.

The most general approach is to minimise a statistic of the sum of the product of the number of units each cluster by the log of the determinants of the within cluster covariance matrix. Minimising this maximises the log-likelihood. This approach allows different clusters to have different sizes, shapes and orientations and this approach can be applied to raw data where scales of dimensions vary widely and dimensions covary. The computation in finding an optimum is unattractive. For seven dimensions, 35 parameters must be estimated for each cluster (7 means and 28 covariances). With multiple clusters large populations are required in order that the parameters may be safely estimated.

A less general approach is to consider the clusters to be of the same size, shape, and orientation; that is, they have identical within cluster covariance matrices. This is the usual model applied in discriminant analysis. This reduces the parameters to be estimated in the seven dimension case to 28 covariances and seven means for each cluster. The statistic to be minimised is the determinant of the within cluster covariance matrix which again maximises the log-likelihood. This approach will tolerate correlated data but the scales of the different dimensions will affect the clustering. As Hartigan (1975: 97) argues, dimensions with the greatest variance are split first into segments with within segment variance more equivalent to the variance on other dimensions. This may be a quite acceptable clustering in some circumstances where clusters are sought to represent the population variance, but this is not a pertinent aim for artefact typing where the smaller dimensions may well be those which display distinct modes.

The least general approach is to assume the clusters are equi-sized and symmetrical, that is they have the same variance on each dimension with each cluster. The within cluster covariance matrix reduces to a diagonal form with equal values on that diagonal. Likelihood is maximised in this case by minimising this common variance. The ML estimate of this variance is SSE/n where n is the number of units. Thus minimising SSE minimises the common variance. Here the clustering is sensitive to correlation between dimensions as well as the scale of dimensions. This approach is the most simple computationally.

The approach followed here was to convert the data to a correlationless and standardised form and apply the least general approach of minimising SSE. Once clustered, converting to Mahalanobis distances for a final reassignment alters the cluster model to the form of intermediate generality above. The optimum thus found is not necessarily the best which might be found by working entirely with this more general procedure.

Reclustering by Mahalanobis distances is an iterative process where within cluster covariances are recalculated after each reassignment pass and the scores readjusted. This iteration was halted when less than five percent of the units shifted in a pass.

Correlation removal

The process used is to standardise each input dimension, including a logarithmic transformation if this reduces the skewness, the covariance matrix is found (A) (the correlation matrix in this case), and then its square root extracted (B) followed by the inverse of the square root matrix (B^{-1}). For each unit the vector of scores used for clustering is found by pre-multiplying the column vector of standardised scores on each dimension by B^{-1}. The correlation matrix for these new scores is the identity matrix.

This process of removing the correlation is equivalent to (and simpler than) extracting principal components from the data, and standardising the principal component scores. Such a set of scores can be converted to a set identical to those produced by the process explained above by an orthoganal rotation of the axes. Distances between any two units are the same in either case.

In converting from Euclidean distances to Mahalanobis distances a similar process is followed but the covariance matrix used to find B^{-1} is the within-cluster matrix. The scores which are premultiplied are those output by the correlation removal procedure above.

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